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TABLE II.

Values for 1891·0.

Name.	πV	V	π and Authority.
η Cassiopeiæ	−0·348	2·3	0″·15 O.Σ.
36 Andromedæ	+0·034		
p Eridani	−0·305		
α Canis Maj.	−5·326	13·4	0·39 Gill and Elkin.
Σ 1037	+0·151		
α Geminorum	+0·112	0·6	0·20 Johnson.
ξ Ursæ Maj.	−0·294	7·4	0·04 Klinkerfues.
γ Virginis	+0·076		
α Centauri	+2·741	3·7	0·74 Gill and Elkin.
ξ Boötis	+0·372		
44 *i* Boötis	−0·082		
η Coronæ Bor.	−0·352		
51 ξ Libræ	+0·184		
ζ Herculis	−0·325		
70 *p* Ophiuchi	+0·197	1·2	0·16 Krueger.
γ Coronæ Austr.	+0·698		
Σ 2173	−0·327		
O.Σ. 235	+0·076		
61 Cygni	−1·173	2·5	0·47 Ball.
„	−0·285	0·7	„ „
ζ Aquarii	+0·041		

On some Celestial Photographs made with a large Portrait Lens at the Lick Observatory. By E. E. Barnard, M.A.

Professor Holden having secured for the Lick Observatory a very large portrait lens (maker, Willard, New York, 1859), I have taken advantage of the opportunity to make with it some experimental long-exposure negatives of the Milky Way, the great nebula of *Andromeda*, and the *Pleiades*. This lens, with the diaphragm removed, has an equivalent aperture of 5·9 inches, and a focal length of 31 inches.

The lens was mounted temporarily in a rough wooden box, and before beginning work the stellar focus was accurately determined by a series of exposures on *Polaris*, &c.

The camera was then strapped firmly upon the tube of the 6½-inch equatoreal, which, with a high power, was used as a following telescope. This instrument, having slow-motion rods in right ascension and declination at the eye-end, was specially

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suited for controlling the motion of its clock, which with the additional weight of the camera required careful and constant attention.

Three negatives of different parts of the Milky Way were made. The cluster M. 11 occupied the centre of one of these plates; another plate covered the region $\alpha = 18^h\ 0^m$, $\delta = -19°$; while the third—in many respects the most remarkable of the Milky Way plates—was in $\alpha = 17^h\ 56^m$, $\delta = -28°$.

This last plate shows an object that I wish to call attention to. For many years I have observed in my comet seeking a most remarkable small inky black hole in a crowded part of the Milky Way. This singular object, with one or two faint stars in its following part, is in about $\alpha = 17^h\ 56^m$, $\delta = -27°\ 50'$ (see *A. N.* 2588, where I have called attention to it). I have not seen this black hole mentioned anywhere. It is about 2′ in diameter, slightly triangular, with a bright orange star on its n. p. border and a beautiful little cluster following. There are other dark holes and vast gaps near this, but nothing so remarkable in the entire circuit of the Milky Way. On the night of August 1 I made a negative of this region—the black hole occupying the centre of the plate—with the intention of showing the hole and the singular configuration of the Milky Way at that point. An exposure of $3^h\ 7^m$ was given, a following star being kept constantly bisected by cross wires in the eyepiece. Not only is the black hole clearly shown in this negative, but the entire cloudlike formation about it with myriads of stars are all faithfully depicted. The exceeding beauty of a glass positive from this plate is beyond description. The other two negatives of the Milky Way are as fine as this, but the Milky Way itself is not so grand.

A negative of the *Pleiades* on August 23, with an exposure of $1^h\ 13^m$, shows the *Merope* nebula quite conspicuously, the small sharp projection of nebulosity from *Electra*, and some of the nebulosity about *Maia* and *Alcyone*. The *Pleiades* at this time, however, were very poorly placed for photographing.

Two negatives were made of the great nebula of *Andromeda*, with exposures of $3^h\ 15^m$ and $4^h\ 18^m$. Throughout these exposures, as in the other cases, the eye was kept constantly fixed on a star bisected by cross wires in the eyepiece, and the clock controlled by the slow-motion rods. Both negatives clearly show the dark spaces and the nebulous rings that were first shown to exist by Mr. Roberts in his exquisite photographs of this nebula. The rings of nebulosity are seen at a glance, though the image on my negatives is on a small scale, the full extent of the nebula covering one inch. I have tried to see these with both the 12-inch and the 6½-inch, but without success, though the so-called "canals" on the north side are clearly seen in both instruments.

In studying the distribution of the stars in space and the structure of the Milky Way, it is clear that any legitimate means of exaggerating peculiarities, or rather of bringing them out

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more strikingly, is greatly to be desired. It would appear that the best way to do this is to photograph large areas of the sky so as to include enough material. If now we reduce this to a small scale, relations that would otherwise escape the eye are brought prominently forward. Acting upon this idea, I have made reduced copies of the above negatives. The result is striking. In the Milky Way pictures the cloudlike masses of stars stand out more boldly, and their forms are more definite than in the original. Reduced in this way, the picture of the region of the *Andromeda* nebula is singularly beautiful; and it shows in a most remarkable manner the peculiar structure of that part of the heavens. The intricate arrangements of the stars in rings and segments are thus shown as nothing else can show them.

Previous to these experiments, at Professor Holden's suggestion, I had attempted to photograph the Milky Way with a 1-inch (9 inches focus) Voigtländer lens, mounted on the 12-inch and the 6½-inch telescopes at different times. These exposures—running up to an hour and a half—showed absolutely no trace of the cloud-forms that are so striking to the eye. The plates were, however, literally sprinkled with stars, most of which were beyond the reach of the eye alone, and therefore much less bright than the Milky Way itself. The sensitive plate was not deceived by a quantity of light as the eye was; but as its action depends upon the intensity of the light, it had gone to work systematically to pick out the individual stellar points of the Milky Way. Of course we know if it had had time enough it would have finally begun the impression of the luminous groundwork. Nothing could show more beautifully the difference between intensity and quantity in the action of light upon the sensitive plate than these attempts to photograph the Milky Way.

With the Willard lens, which gave essentially thirty-six times as much light for the stars and three times that for the Milky Way, considered as a surface, three hours were required to show the cloud-forms.

Upon examining these plates, especially the one in $17^{h}\ 56^{m}$ $-28°$, it will be seen that we have here opened up for us a magnificent field of investigation. It is only necessary to mention the very great differences in the delineation of even the more conspicuous parts of the Milky Way, as shown on different star charts, to see that we have not the means in such charts to make anything like a comprehensive study of the Milky Way. Eyes differ so much, and astronomers, as a rule, are such very poor artists, that we may never expect to get anything like a fair delineation of the Milky Way by the human hand alone; and if we could, the human eye is too feeble to grasp the more important details, and the largest field of any telescope is too small to trace such large features with any accuracy. Observing and charting the stars does not aid us at all, for the true form of the Milky

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FIG. 1. R.A. 17h. 56m. Decl. $-28°$, 1889, Aug. 1, 8h. 56m. to 12h. 3m. (1 in. = 1°·8).

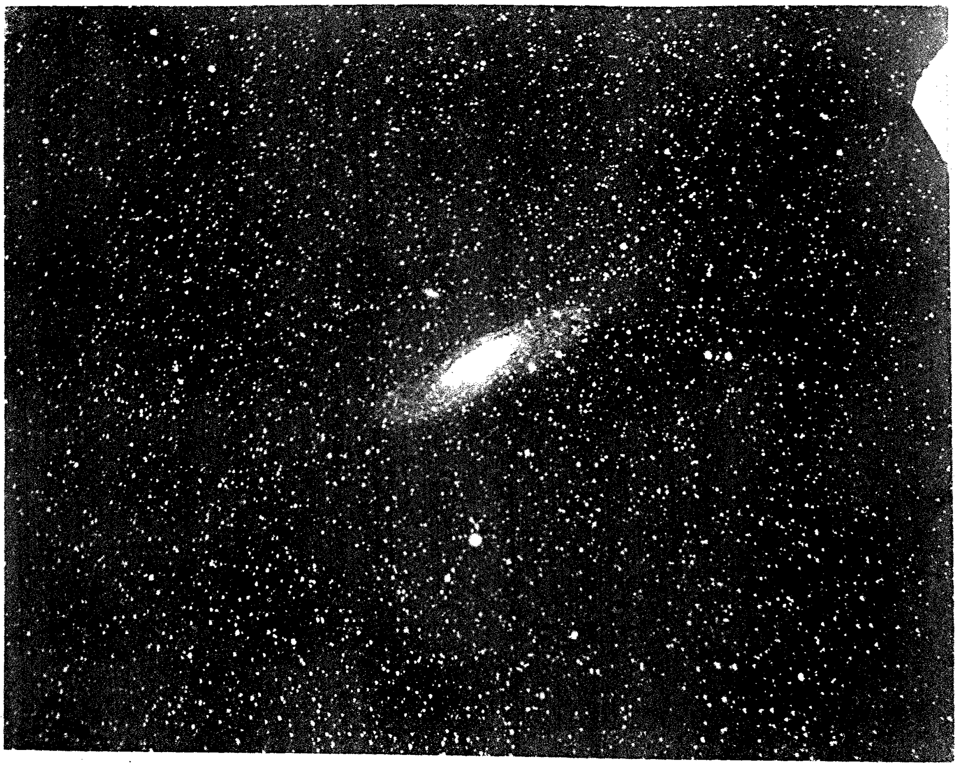

FIG. 2. M. 31, 1889, Aug. 26, 8h. 8m. to 12h. 25m. (1 in. = 1°·8).

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Way does not depend on stars as bright as the ninth and tenth magnitude, but upon the millions of smaller stars, most of which are beyond the reach of any telescope. The photographic telescopes that are now being made—except, indeed, the Bruce telescope—will give us very little information about the structure of the Milky Way, as the field of view will be too small, and they will not show the cloud-forms.

What is wanted, therefore, is a photographic chart of the Milky Way made with a short-focus lens of the largest attainable aperture—one that will cover a field of at least one hundred square degrees—with an exposure time that will show the luminosity of the Milky Way. Such a chart can easily be made in one year's time, and must be of inestimable value. I am happy to make the first contribution to such a map.

I hope when the 6½-inch returns to the observatory to be able to resume the photography of the Milky Way.

The success of these long exposures suggests the possibility of extending the time of exposure through several successive nights, the same following star being used night after night, the plate remaining undisturbed, but carefully protected from light during the day.

I take pleasure, through the courtesy of Professor Holden, in presenting to the Royal Astronomical Society some glass positives of these negatives, and also an album with silver prints, both negative and positive, from the same.

Descriptions of the Photographs and Positives.

R.A. $18^h\ 0^m$—19°. Album, pp. 4 and 5. 1889, July 28.—This is a remarkable region, but the exposure was too short to show it well, clouds having interfered. The adopted time of exposure is $1^h\ 17^m\pm$, with the aperture reduced to 4 inches.

The striking feature about this region is a series of vacancies that are fairly well shown in the print just below the dense mass of stars (p. 5). Another striking feature is the presence of a great many stars with ellipses, or partial ellipses, of small stars about them, the larger star apparently occupying the focus of the ellipse. One of the three large stars (p. 5) to the left (south) on the picture is a good example of this. The *Omega* nebula is shown on this print, to the right near the edge. In connection with this picture it is well to read Secchi's remarks on this same region, as given by Webb, *Celestial Objects*, p. 385, 4th edition.

Region near M. 11. Album, pp. 2 and 3. 1889, August 2, from $11^h\ 8^m$ to $13^h\ 53^m$.—Here the cloudlike forms, partially resolved into stars, are finely shown. M. 11 is placed on the extreme N. edge of the connecting mass that extends between two vast clouds of stars.

R.A. $17^h\ 56^m$, $\delta = -28°$. Album, pp. 1, 6, 7. 1889, August 1, $8^h\ 56^m$ to $12^h\ 3^m$.—This remarkable picture shows the cloud-

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forms like waves of spray. A dark curving lane runs from the lower left-hand portion of the picture, p. 6 (S.W.), and curves gracefully upwards to the place of *Jupiter*. It is singularly like the stem of a great leaf. At the middle of the picture it is seen to pass behind some of the clouds of stars and emerge beyond, showing us clearly which part of the Milky Way at that point is nearest to us. Imagination may aid one, but it looks as if the lines of the cloud-forms, and of the stars and vacancies, all run more or less concentric with this extensive lane. In the reduced glass positive, this lane and its connecting branches come out grandly (the glass positives should be examined with the light of a lamp through a white porcelain shade, or against the sky away from the region of the Sun). In this positive the masses of stars to the north-west of the middle resemble breaking spray. The black hole is seen slightly to the left of the centre, with the small cluster as a white spot close to the right of it. The planet *Jupiter*, at the top of the picture (not shown in the plate), is very large, from the excessive over-exposure, and mingles its light with that of the trifid nebula (Fig. 1, plate 3).

The Great Nebula of *Andromeda*. Album, pp. 8, 9, 10, 11. 1889, August 26, $8^h\ 8^m$ to $12^h\ 25^m$.—I would call special attention to the *negative* print on p. 10, where the entire 8 × 10 negative is reduced to a scale of $5^\circ{\cdot}3$ to the inch. Above the preceding end of the nebula, and apparently connected with it, is a diffusion of light for some five degrees to the north-west, that looks very much like nebulosity. That this is real nebulosity I am somewhat doubtful. Yet the appearance is singularly real. It is possible that this is a reflection from the lenses, in some manner due to the very long exposure ($4^h\ 18^m$ of sid. time). It has not been possible for me to verify it by repeating the exposure, but if it is true nebulosity, this plate will have been the first to show it (Fig. 2, plate 3).

It is needless to call attention to the remarkable structure of this part of the sky, as shown on this reduced picture, in contrast with that shown, say at $17^h\ 56^m$—28°. The singular lanes of vacancies to the north-east of the nebula (p. 10) are so striking that the eye catches them at once. By carefully counting areas, I have estimated that there are 64,000 stars distinctly visible on the original 10 × 8 plates of this region.

It is unnecessary for me to go into any further description of the arrangements of the stars in these negatives, as that has already been thoroughly done by Professor Holden, in his communication on the subject. (See *Monthly Notices*, vol. l. p. 61.)

Mount Hamilton:
1890 *January* 1.